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INTERVIEW IN LAND CONSOLIDATION USING GENETIC ALGORITHM

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ABSTRACT. It is called farming, which is made on land to produce useful and essential products for life. Agriculture has ever been the main source of human life. However, as the human population are growing day by day, the earth presence in the world remains the same, even decreasing. In Turkey, due to various reasons agricultural land is small, fragmented and scattered. This situation affects the agricultural productivity in negative direction. In order to increase productivity legal measures, which prevent further fragmentation of agricultural land, should be taken first and then the existing fragmented structure should be reassembled and regulated according to the principles of modern agricultural management, i.e. land consolidation (LC) must be done. LC process consists of various time consuming and complex stages. In this study, it has been emphasized that the interview stage of the land consolidation process, which is currently carried out manually, is carried out automatically. In order to solve problem genetic algorithm (GA) has been applied on the problem and the results obtained have been evaluated.

1. INTRODUCTION

In recent years, agriculture has become an important sector for societies due to population growth. The hunger problem which is seen in some countries and risk of emerging in other countries makes people anxious [1]. In Turkey, due to various reasons, agricultural land is small, fragmented and scattered. Also, the land used for agriculture is constantly fragmented, therefore already small-scale enterprises are getting smaller. This situation affects the agricultural productivity in negative direction by causing the increase of workforce and cost. Land fragmentation is caused by the separation of land, which belongs to an enterprise in rural areas, into many different places and many pieces [2]. It is very common in developed countries

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[3] and reduces farm profitability [4]. Land fragmentation is one of the most important problems for sustainable agriculture. Since it is not possible to increase the area to be farmed, the best solution in this case is to use the existing soils in the most efficient way. For this, legal measures which prevent further fragmentation of agricultural land should be taken first, and then the existing fragmented structure should be reassembled and regulated according to the principles of modern agricultural management, i.e. LC must be done. Land consolidation is one of the important means of increasing productivity in agricultural production. Not only does LC consolidates fragmented land, but also it improves the standards of landowners in agriculture, technical, social and cultural areas [5]. In this respect, land consolidation both improves agriculture and contributes to the development of natural resources and rural development [6]. Land consolidation process consists of various stages. Figure 1 shows the flow chart of LC.

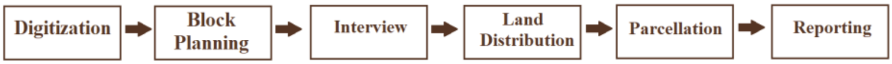


Figure 1. Main stages of LC

As seen in the Figure 1, after the completion of block planning, interview stage starts. At this phase, blocks in which landowners (farmers or enterprises) want to take part are determined. The information obtained in these stage is given as input to the distribution phase. Therefore, interview determines the blocks which landowners will take place after consolidation, so it directly affects the result of consolidation. Today, in Turkey these process is carried out manually by a technician. Technician goes to project field and get farmer's preferences. After that, these choices are considered according to certain criteria, because an interview that does not comply with criteria affects post-interview stages of LC process negatively. The biggest problem in these phase is inability of obtain land owners preferences. Another problem is that many landowners want to choose blocks in the most valuable earth, even though they have no parcels in these blocks. In this case, those who will make LC will go to project area again and try to get preferences. Retrieval of preferences and repetition of same process cause an extension of interview process. Also, interviews which are not proper lead to the overloading of certain blocks and thus requests of farmers will not to be fulfilled. The land consolidation work has been going on since 1960s [7], however there has been no study to automatically generate interview lists. Some previous studies have been undertaken with the idea of mathematical optimization for automatic reallocation [8]. Other studies have focused on the land partitioning [9].

In this study, it is aimed to prevent negativities encountered at interview process, to determine automatically (independently from interviewer) the most appropriate blocks (interview lists) and to save labor and time in the interview process. In order to solve problem, Genetic Algorithm (GA) has been used on problem and the results have been evaluated [10].

2. Material and Method

2.1 Alanözü Village

In this project, one of the working area is Alanözü village of Güneysınır district of Konya. The reason for choosing this area is that land consolidation work was completed in this village, so it is easy to get the necessary information. Alanözü has 18 blocks, 333 enterprises, 630 whole cadastral parcels and 53 fragmented cadastral parcels (total 683 parcels). The total area of village is 154 hectare area (ha), but 152.69 ha area can be distributed. The average area of cadastral parcels is approximately 2235 m^2 and the number of parcels per establishment is 2.08. In the village, only 260 parcels benefit directly from the transport system [11]. Figure 2 shows the cadastral state of Alanözü village [12].

Figure 2. Cadastral state of Alanözü

2.2 Üçhüyük Village

Üçhüyük, which is located in Çumra district of Konya, is a small village. The consolidation process of Üçhüyük was completed in 2016 by the Provincial Directorate of Agriculture of Konya with auction. This village has 875.69 hectare area, 275 enterprises and 265 cadastral parcels. The cadastral state of Üçhüyük is shown in Figure 3 [13].

Figure 3. Cadastral state of Üçhüyük

2.3 Genetic Algorithm (GA)

The genetic algorithm, which was discovered in 1975 by Netherlands, is a random search algorithm [14]. It is based on the Darwinian theory of evolution. GA basically consists of three-step process: Reproduction, crossover and mutation [15]. Reproduction allows good individuals to be transferred to future generations. Crossover is creation of new individuals by crossing two individuals according to crossover method. Mutations are random changes in individuals to prevent the population from becoming same (to preserve diversity). The flow chart of GA is shown in Figure 4.

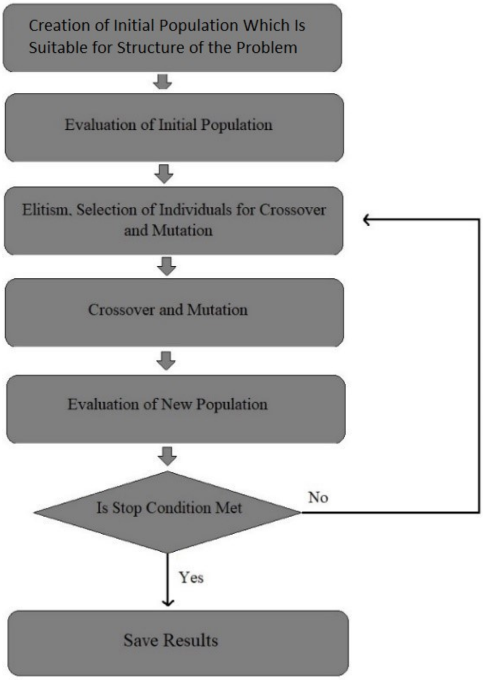


Figure 4. Flow chart of GA

GA can be directly applied to continuous and discrete problems and it has an ease implementation. Therefore, genetic algorithm has been used on many real-world problems ranging from engineering applications to healthcare and will go on to be used. Simulating correlation of binary data from biomedical research [16], distribution of land with genetic algorithm [17], automated land partitioning using genetic algorithms [11] are some examples of applications of GA in real world problems. In this study GA has been used to place the parcels in most appropriate blocks automatically according to the criteria mentioned in the introduction.

3. Experimental Setup

Study carried out for making interview lists can be examined under two stages which are preprocessing and application of genetic algorithm on problem.

3.1 Preprocessing

Fixed facilities (houses, wells, etc.) are not movable and they are very important for enterprises. Therefore, landowners do not want to change the location of the fixed facilities [13]. In order to both decrease the number of parcels which are used in genetic algorithm and to fulfill the requests of enterprises, preprocessing is carried out on fixed facilities. For this, the parcels containing fixed facilities are placed in the block where they are located and the area of these parcels are reduced from the block areas. Also, to keep location of these parcels unchanged, they are not used in GA. When the placement of fixed facilities has been completed, enterprise's parcels which all are in same block are placed directly in that block. Thus, enterprises that do not have parcels in other blocks are prevented from going to these blocks. Thanks to these two pre-processing, both the number of parcels to be used in genetic algorithm are reduced and the fixed facilities of enterprises are protected.

3.2. Application of GA on Problem

In order to solve the interview problem with GA, firstly it is necessary to create an objective function which fulfills the criteria of problem. The problem has four basic criteria which are as follows:

- All blocks or nearly all of the blocks should be full or close to full.
- Block fullness rates should not be less than 70% and more than 120%.
- The preferences created for the parcels should be one of the following four blocks: the block where the fixed facilities are located, the block with the largest parcel, the block with the second largest parcel, and the block with the parcel density.
- Enterprises cannot take place in blocks where they do not have any parcels.

An objective function to evaluate first three criteria equally has been defined. Function consists of three stages. In equation (3.1), the formula used to calculate the penalty point for first criterion (*PP1*) is shown.

$$PP_1 = \sum_{i=1}^{BC}(abs(TAA_i)/BA_i)\,/BC \qquad (3.1)$$

In here, TAA_i indicates the remaining or increasing area in *ith* block, when parcels of enterprise are placed in their first preference. If TAA_i is negative, it means that the block is overflowed, and if it is positive, it means that the block is empty. BA_i is area of *ith* block and *BC* represents the number of blocks. Equation (3.2) shows the formula used to calculate the TAA_i.

$$TAA_i = \left(BA_i - \sum_{j=1}^{ParCou} ParA_{ij}\right) \qquad (3.2)$$

In here, *ParCou* is the number of parcels placed in *ith* block, $ParA_{ij}$ is the area of *jth* parcel, which is placed in *ith* block. After the overflow or remaining areas are calculated for each block, these values are summed. The penalty point for balancing blocks is obtained by dividing the total value obtained by the number of blocks. After calculating the penalty points for the block fullness rates, the second penalty points for the block fullness rates are calculated. Equation (3.3) gives the formula used to calculate the second penalty score (*PP2*).

$$PP_2 = (\sum_{i=1}^{n} BPP_i)/BC \tag{3.3}$$

Here, *BPP* represents the penalty point for the block fullness rates. BPP has the following values according to block occupancy rates:

- 0 for 95% - 100%
- 0.1% for 90% - 95%
- 0.2% for 80% - 90%
- 5 for 70% - 80%
- 1 for < 70%
- 0.1% for 100% - 105%
- 0.2% for 105% - 110%
- 0.5% for 110% - 120%
- 1 for > 120%

BPP values have been determined according to test results which were performed previously. In the experiments conducted, the best results for study areas were taken at the intervals given above. When the intervals were set wider, the block occupancy rates varied widely, and when they were taken narrower, there was no improvement in the results. Finally, preference penalties for preferences which were created for parcels have been calculated. In equation (3.4) is shown the formula used to calculate the penalty score for preferences (third criterion).

$$PP_3 = \left(\sum_{i=1}^{ParCou} PrePenPo_i\right)/ParCou \tag{3.4}$$

Here, $PrePenPo_i$ shows the preference penalty score of *ith* parcel. *PrePenPo* is 0 for fixed facility block, 0.1 for block with the largest parcel, 0.2 for block with the second largest parcel, 0.3 for block with the parcel density, and 1 for block which is not one of these four blocks. *PrePenPo* is determined for all parcels found in the working field and these values are summed. Penalty score that controls the success of the preferences is calculated by dividing the total score obtained by the total number of parcels in study area. Equation (3.5) shows the exact form of the objective function.

$$PenaltyPoint = PP_1 + PP_2 + PP_3 \tag{3.5}$$

In this study, number of digits of penalty points have been equalized in order to prevent criteria from deactivating each other and to ensure that each criterion has equal effect in the objective function.

After the preprocessing has been completed, the GA is applied to interview problem by using the objective function. To solve problem, firstly initial population which is suitable for structure of problem is created. An individual consists of enterprise number, randomly listed parcels and two or three different chooses for parcels:

- Enterprise number is a unique integer which belongs to an enterprise.
- Randomly listed parcels are parcel numbers which belong to enterprise.
- Choses are block numbers where enterprise parcels take place. Table 1 shows part of an individual.

pop(1).individual

Fields	enterprise	parNum	blocks
1	190	[2597 2758 577 636 302]	5x3 double
2	154	2817	[156 154]
3	268	[247 641]	[160 164;160 164]
4	47	[740 769 2661 739]	4x3 double
5	11	[586 226]	[160 165 164;164 160 165]
6	142	[249 2763]	[149 151 160;149 160 151]
7	141	[725 307 714 727]	4x3 double
8	269	[671 672]	[164 162 163;163 164 162]
9	91	[268 292 2654]	[156 157 152;152 157 156;152 157 156]
10	181	[2705 2820 731 2701 2706 2702]	6x3 double
11	263	[2737 786]	[158 161 155;161 155 158]
12	222	[2836 2831 2774]	[156 157 149;157 149 156;157 156 149]
13	148	2781	[149 153 154]
14	186	262	[157 161 158]
15	82	550	[164 165]
16	291	2838	[157 156]
17	257	[2825 843 710 846 683 776 682]	7x3 double
18	251	[570 719 319 329 1000 718]	6x3 double
19	226	[327 629]	[157 158 163;158 163 157]
20	210	[682 710 2825 683 776 2677 846 843]	8x3 double
21	216	[696 2725 787 665]	4x3 double
22	73	850	[159 158]

Table 1. Part of a sample individual

Once the initial population has been created, the fitness values of individuals are calculated using the objective function. In order to protect best individuals, the best candidate solutions in a certain percentage are transferred to next population without any processing. Individuals to be used in crossover are determined by triple tournament selection method. In this selection method, individuals with high quality are more likely to be selected. As a crossover method, single point crossover has been used. Crossover process has been carried out as follows:

- Two individuals are randomly selected.
- For crossover, enterprises are randomly chosen up to predetermined number of percentages.
- In two individuals, preferences of a random number of parcels are exchanged. Figure 5 shows a crossover example.

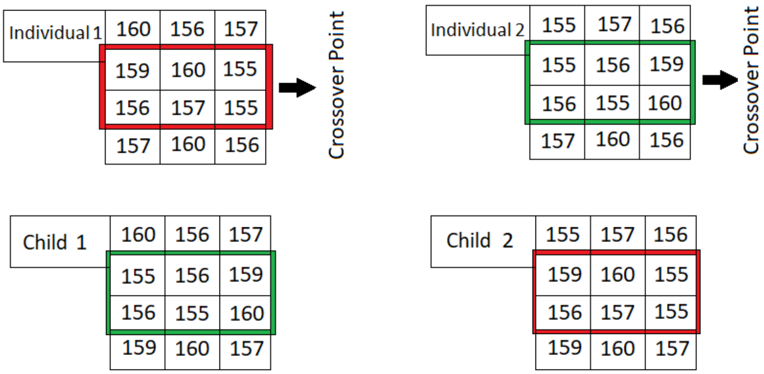


Figure 5. Crossover example.

After crossover has been done, mutation process is started. Value change mutation method is applied in a low percentage to ensure diversity of population. Implementation of mutation process is as follows:

- A random number between 0 and 1 is generated for each individual. If this number is greater than the predetermined mutation rate, mutation is applied to this individual. If not, mutation is not applied to individual
- The number of enterprises that will be get mutated is randomly determined according to a predetermined percentage value.
- It is again randomly determined which of the parcels of the enterprises will be get mutation. Figure 6 shows a sample of mutation.

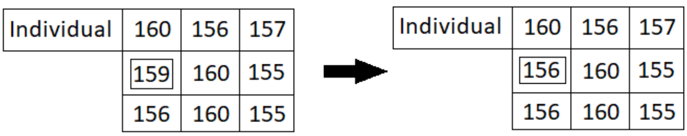


Figure 6. Mutation example

After mutation process, following procedure is carried out to prevent a great diversification of preferences for enterprise parcels:

- It is determined for each preference how many of them created for enterprise parcels.
- After preference numbers of enterprises are determined, if all preferences are different from each other, one of preferences which is randomly determined is assigned to preferences of business parcels which are also randomly determined.

In this way, parcels are gathered together by avoiding too many variations of preferences. A sample assignment is shown in Figure 7.

Individual			
	160	156	157
	156	160	157
	155	156	157
	156	155	159
	159	156	155
	155	156	159

New Individual			
	160	156	157
	156	160	157
	156	160	157
	156	155	159
	156	160	157
	155	156	159

Number of Preference

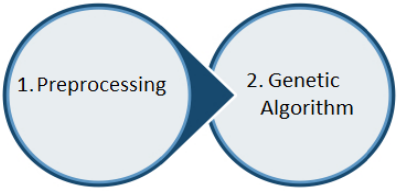
160	156	157	1
156	160	157	1
155	156	157	1
156	155	159	1
159	156	155	1
155	156	159	1

Number of Preference

160	156	157	1
156	160	157	3
156	155	159	1
155	156	159	1

Figure 7. Sample assignment

A new population is obtained after controlling of preference diversity. This population is evaluated by sending to the objective function. Until the stop condition is met, elitism, selection, crossover and mutation process are repeated. Figure 8 shows the flow diagram for solution of interview problem using GA.



1. Creation of initial population
2. Evaluation of the initial population
3. Elitism, selection
4. Crossover and mutation
5. New population
6. Evaluation of the new population
7. Is stop condition met
    8. If it is, save results
    9. If it is not, return to step 3

Figure 8. Flowchart for solution of interview problem using GA.

4. Results & Conclusion

In this section, performance evaluations of genetic algorithm on data set of Alanözü and Üçhüyük village is presented.

4.1 Parameter Settings

All experiments for interview problem have been executed on a machine with i5-5200u processor, 2.20 Ghz and 8GB RAM and all codes have been written in MATLAB 2014. Parameters which are used in genetic algorithm have been set as follows:

- Crossover rate is 0.8, crossover is applied to 90% of enterprises.
- Mutation rate is 0.1, 90% of enterprises are get mutated.

In order to determine robustness and effectiveness of the method more accurately, GA has been executed on 40 times on data sets. 20 times are for 1000 generations and 20 times are for 2000 generations. Accuracy rates for working areas have been obtained according to actual distribution results which were get by a technician.

4.2 Experimental Results for Alanözü

Genetic algorithm has been applied to project area of Alanözü village of Konya. Alanözü village, which is a small working area in terms of land size, needs to land consolidation because of containing a large number of parcels. Table 2 shows average, best and worst fitness values and preference success rates (*PreSucRat*) for these fitness values.

Table 2. Experimental results for Alanözü

Generation		Fitness Value	Preference Success Rate
1000	Best	0.5200	75.7085
	Mean	0.7346	74.4690
	Worst	1.6162	72.6721
2000	Best	0.4860	76.1134
	Mean	0.7100	74.7165
	Worst	1.4570	74.2915

When Table 2 is examined, it is seen that 2000 generations have the best preference success rate and fitness value. 1000 generations yield average 74.47% accuracy rate, while 2000 generations yield 74.72%. Figure 9 shows the block fullness rates of best individual for 1000 generations and Figure 10 for 2000 generations.

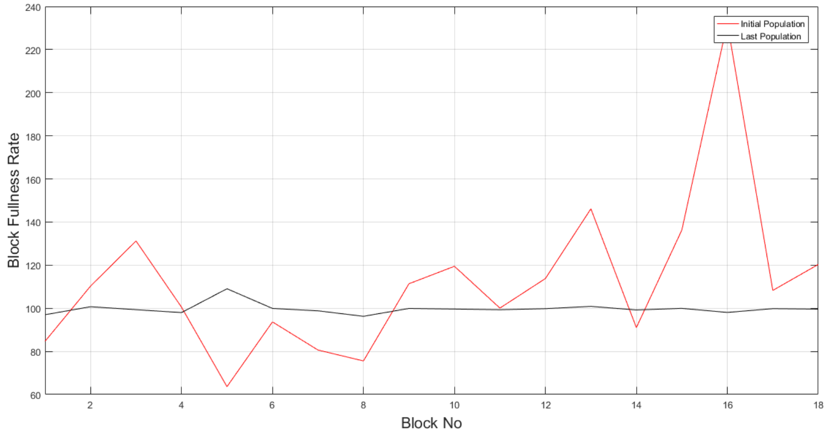


Figure 9. Block fullness rates for 1000 generations

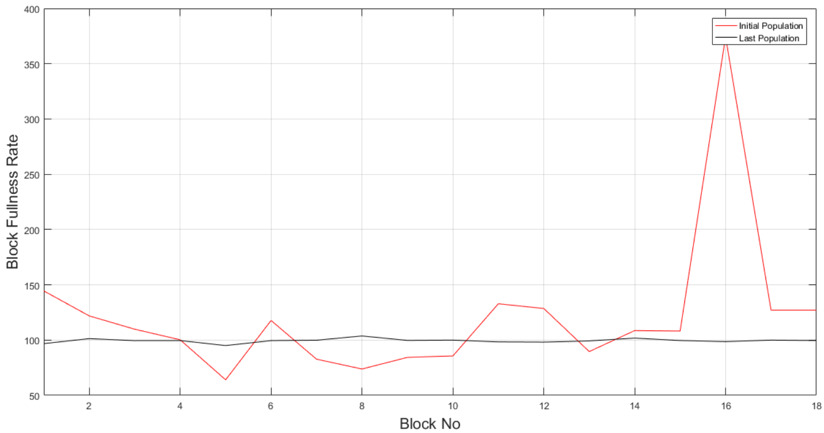


Figure 10. Block fullness rates for 2000 generations

When Figure 9 is examined, the block fullness rates of the starting population are much dispersed and 6 blocks are not in the desired range which is between %70 and %120. In the last population, occupancy rates of nearly whole blocks are close to 100% and the occupancy rates of all blocks are within the desired fullness rate. When Figure 10 is examined, the block fullness rates of the starting population are much dispersed too and 9 blocks are not in the desired range. In the population obtained after applying genetic algorithm, occupancy rates of nearly whole blocks are close to 100% and the occupancy rates of all blocks are within the desired range. Figure 11 shows the convergence graph of best individual for 1000 generations and Figure

12 for 2000 generations. As seen from the Figure 11 and 12, both generations have similar convergence speed.

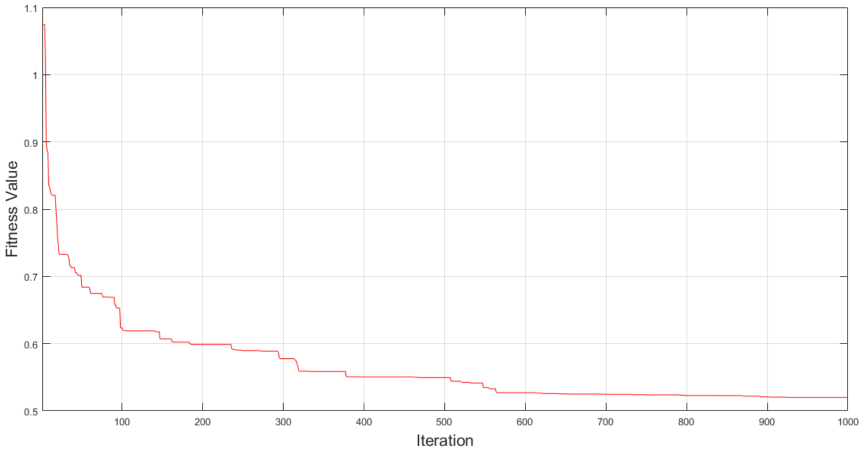


Figure 11. Convergence graph of best individual for 1000 generations

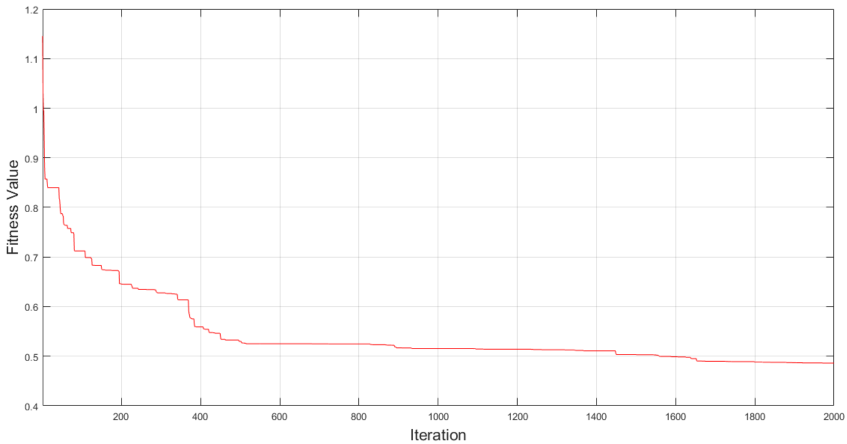


Figure 12. Convergence graph of best individual for 2000 generations.

4.3 Experimental Results for Üçhüyük

Genetic algorithm also has been applied to project area of Üçhüyük village of Konya. Üçhüyük is bigger than Alanözü in terms of land size, however it has less parcels. Table 3 shows average, best and worst fitness values and preference success rates for these fitness values.

Table 3. Experimental results for Üçhüyük

Generation		Fitness Value	Preference Success Rate
1000	Best	0.3068	87.2516
	Mean	0.5461	84.7103
	Worst	1.3726	83.6093
2000	Best	0.3368	88.0795
	Mean	0.5934	86.0624
	Worst	1.4221	84.1060

When Table 3 is examined, it is seen that 2000 generations have the best preference success rate while 1000 generations have best fitness value. 1000 generations also have better mean and worst fitness values than 2000 generations. 2000 generations have best preference success rate for mean and worst fitness values. Figure 13 shows the block fullness rates of best individual for 1000 generations and Figure 14 for 2000 generations.

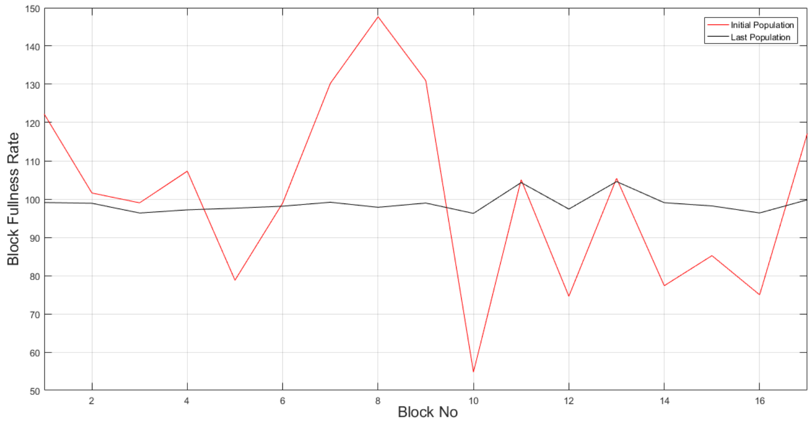


Figure 13. Block fullness rates for 1000 generations

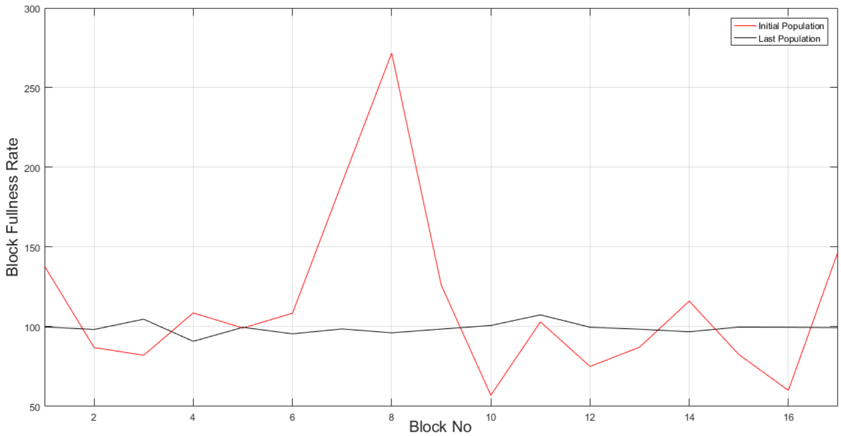


Figure 14. Block fullness rates for 2000 generations

When Figure 13 is examined, the block fullness rates of the starting population are much dispersed and 5 blocks are not in the desired range which is between %70 and %120. In the last population, occupancy rates of nearly whole blocks are close to 100% and the occupancy rates of all blocks are within the desired fullness rate. When Figure 14 is examined, the block fullness rates of the starting population are much dispersed too and 7 blocks are not in the desired range. In the population obtained after applying genetic algorithm, occupancy rates of nearly whole blocks are close to 100% and the occupancy rates of all blocks are within the desired range.

Figure 15 shows the convergence graph of best individual for 1000 generations and Figure 16 for 2000 generations. As seen from the Figure 15 and 16, 1000 generations have better convergence speed than 2000 generations.

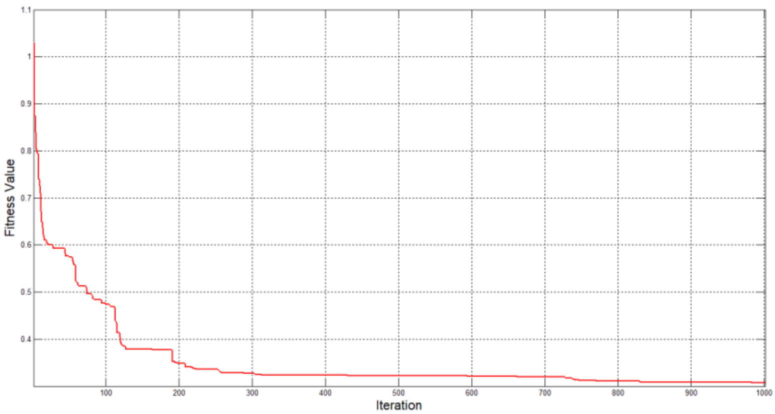


Figure 15. Convergence graph of best individual for 1000 generations

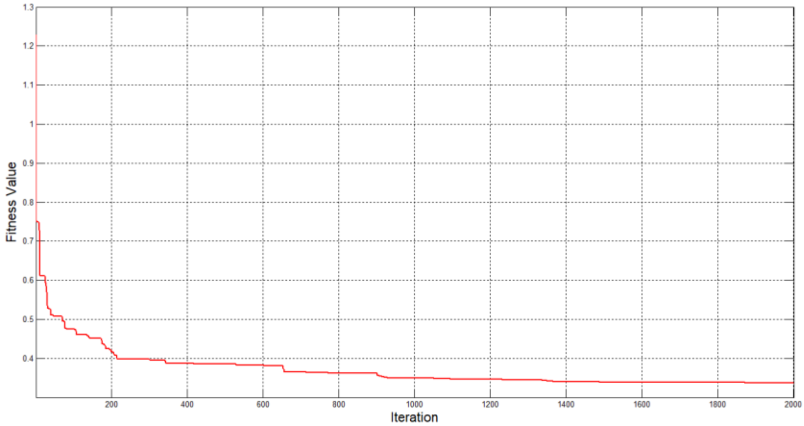


Figure 16. Convergence graph of best individual for 2000 generations.

5. Conclusion

In this study, it has been emphasized that the interview stage of the land consolidation process, which is currently carried out manually, is carried out automatically. In order to solve problem, pre-processing has been performed firstly. After the pre-processing has been completed, the genetic algorithm has been applied to interview problem by using elitism, tournament selection, crossover and mutation process. According to the experimental results, the method has yielded average 74.5% accuracy rate for Alanözü village and 85.39% for Üçhüyük project area. The fact that this study is among the first studies carried out in interview has a great importance. However, data used in this study are limited, therefore, it is thought that better results can be obtained in the future studies with using more data. Besides, the performance results obtained by using different methods can be compared with the results obtained by using GA.

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